



(12) **United States Patent**  
**Pappalardo**

(10) **Patent No.:** **US 9,242,214 B2**  
(45) **Date of Patent:** **Jan. 26, 2016**

(54) **RECONFIGURABLE MIXING BAFFLE FOR  
STATIC MIXER AND METHOD FOR  
MAKING A STATIC MIXER**

(71) Applicant: **Nordson Corporation**, Westlake, OH  
(US)

(72) Inventor: **Matthew E. Pappalardo**, Ewing, NJ  
(US)

(73) Assignee: **NORDSON CORPORATION**,  
Westlake, OH (US)

(\*) Notice: Subject to any disclaimer, the term of this  
patent is extended or adjusted under 35  
U.S.C. 154(b) by 583 days.

(21) Appl. No.: **13/658,948**

(22) Filed: **Oct. 24, 2012**

(65) **Prior Publication Data**

US 2013/0107660 A1 May 2, 2013

**Related U.S. Application Data**

(60) Provisional application No. 61/553,575, filed on Oct.  
31, 2011.

(51) **Int. Cl.**  
**B01F 5/06** (2006.01)  
**B01F 15/00** (2006.01)

(52) **U.S. Cl.**  
CPC ..... **B01F 5/0617** (2013.01); **B01F 5/0619**  
(2013.01); **B01F 5/0641** (2013.01); **B01F**  
**15/00928** (2013.01); **B01F 2005/0637**  
(2013.01); **Y10T 29/4998** (2015.01)

(58) **Field of Classification Search**  
CPC .... B01F 5/0612; B01F 5/0616; B01F 5/0618;  
B01F 2005/0537; B01F 5/0611  
USPC ..... 366/337, 338, 336, 340  
See application file for complete search history.

(56) **References Cited**

**U.S. PATENT DOCUMENTS**

3,783,938 A 1/1974 Chartet  
3,837,396 A 9/1974 Newton  
(Continued)

**FOREIGN PATENT DOCUMENTS**

DE 1939668 U 6/1966  
EP 0655275 A1 5/1995  
(Continued)

**OTHER PUBLICATIONS**

The International Bureau of WIPO, International Preliminary Report  
on Patentability in PCT Application No. PCT/US2012/061835, May  
15, 2014.

(Continued)

*Primary Examiner* — Charles Cooley

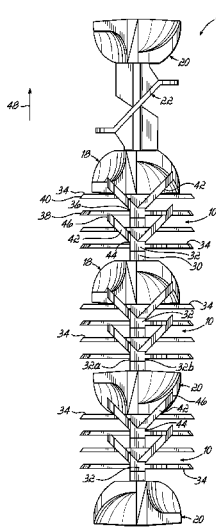
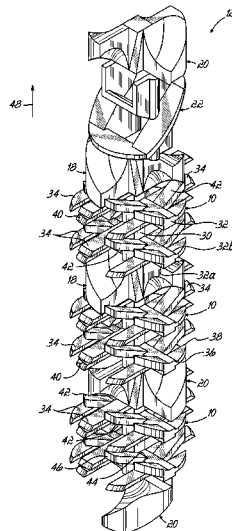
*Assistant Examiner* — Marc C Howell

(74) *Attorney, Agent, or Firm* — Baker & Hostetler LLP

(57) **ABSTRACT**

A mixing baffle for mixing a fluid flow in a static mixer includes a mixing element support structure extending along a longitudinal direction and a first set of moveable mixing elements coupled to the mixing element support structure. The first set of moveable mixing elements is formed in a first configuration and moves to a second configuration when the mixing baffle is inserted into a tubular conduit. In the second configuration, the first set of moveable mixing elements is optimized for mixing fluids and defines a plurality of undercuts that are difficult to mold. The mixing baffle may also include a second set of stationary mixing elements that interlace with the first set of moveable mixing elements when the first set of moveable mixing elements moves to the second configuration.

**28 Claims, 11 Drawing Sheets**



# US 9,242,214 B2

Page 2

(56)

## References Cited

### U.S. PATENT DOCUMENTS

3,903,962 A 9/1975 Newton  
4,220,416 A 9/1980 Brauner et al.  
4,265,275 A 5/1981 Heller et al.  
4,497,751 A 2/1985 Pluss  
4,826,089 A \* 5/1989 Psaltopoulos ..... B01F 5/0616  
241/154  
4,878,624 A \* 11/1989 Psaltopoulos ..... B01F 5/0616  
241/21  
4,899,812 A \* 2/1990 Altoz ..... B01F 5/0616  
138/38  
5,378,063 A 1/1995 Tsukada

5,492,408 A \* 2/1996 Alfare ..... 366/337  
5,520,460 A 5/1996 Lantz  
6,478,133 B1 11/2002 Woignier et al.

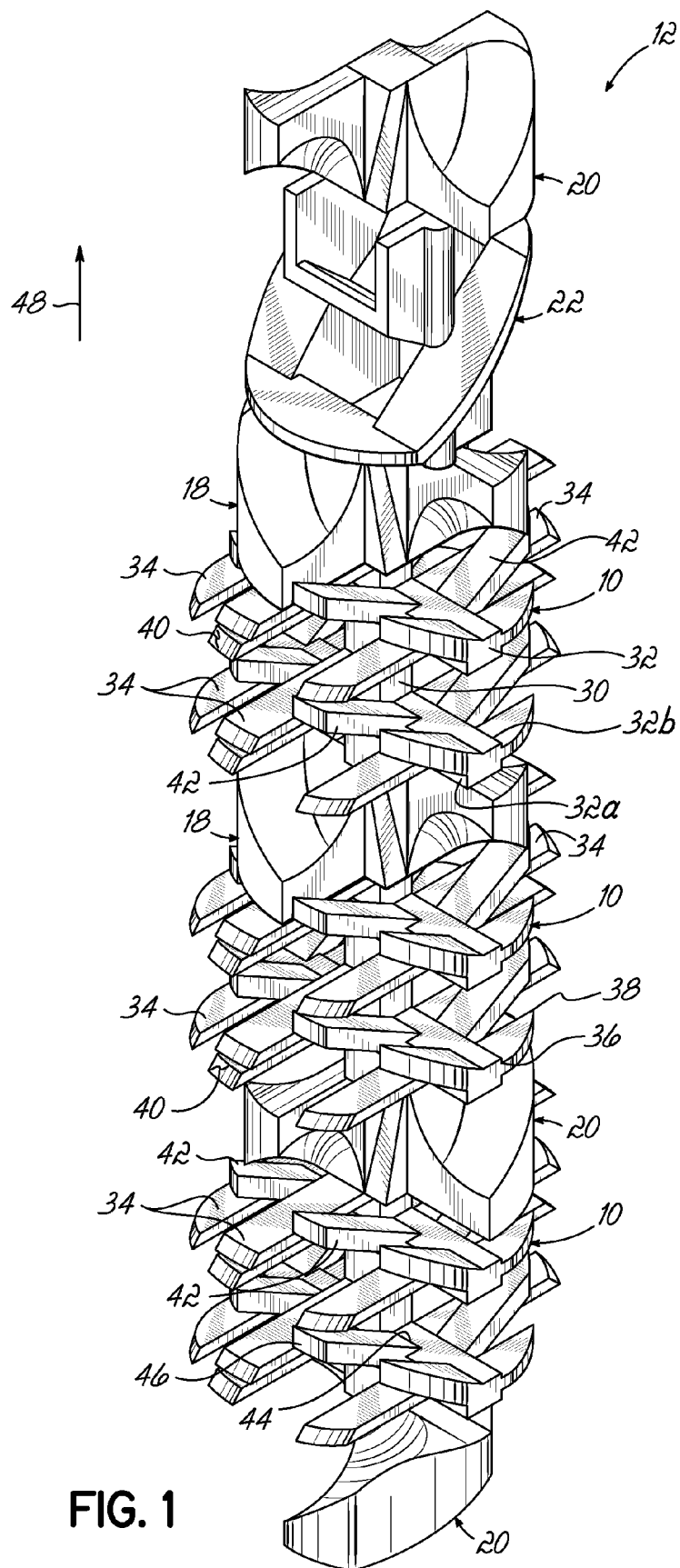
### FOREIGN PATENT DOCUMENTS

EP 1815904 A1 8/2007  
WO 9900180 A1 1/1999

### OTHER PUBLICATIONS

European Patent Office, International Search Report and Written  
Opinion in PCT Application No. PCT/US2012/061835, Feb. 18,  
2013.

\* cited by examiner



**FIG. 1**

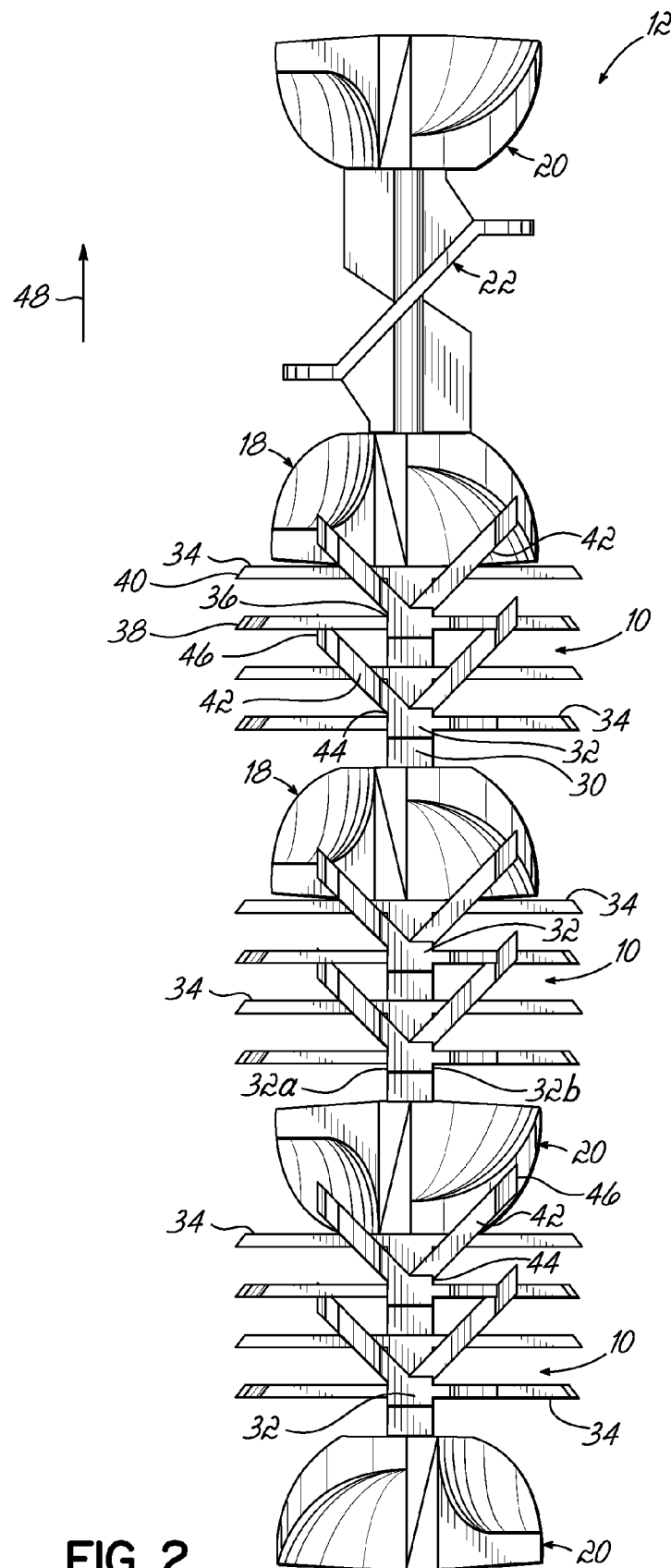
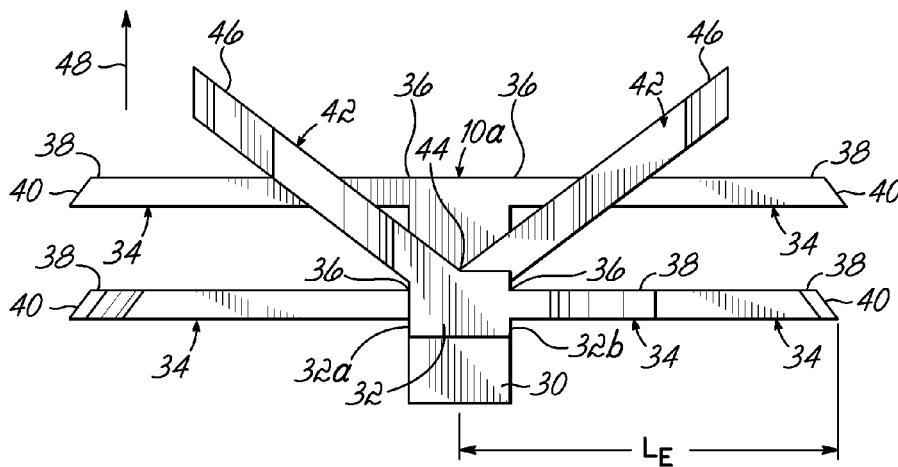
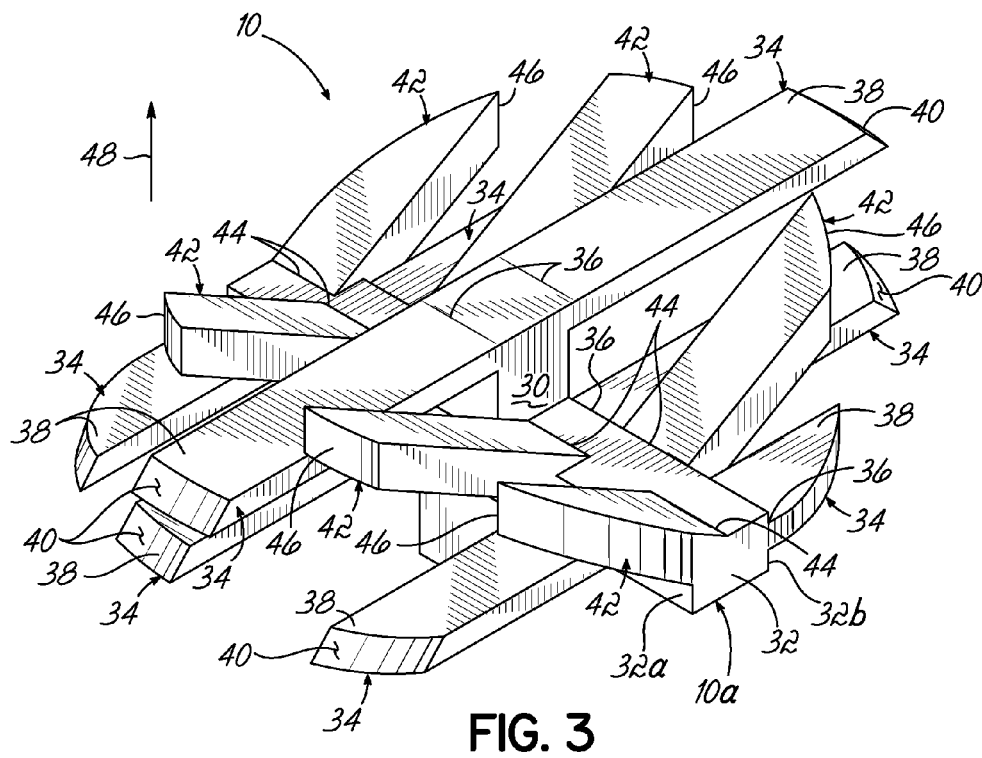


FIG. 2



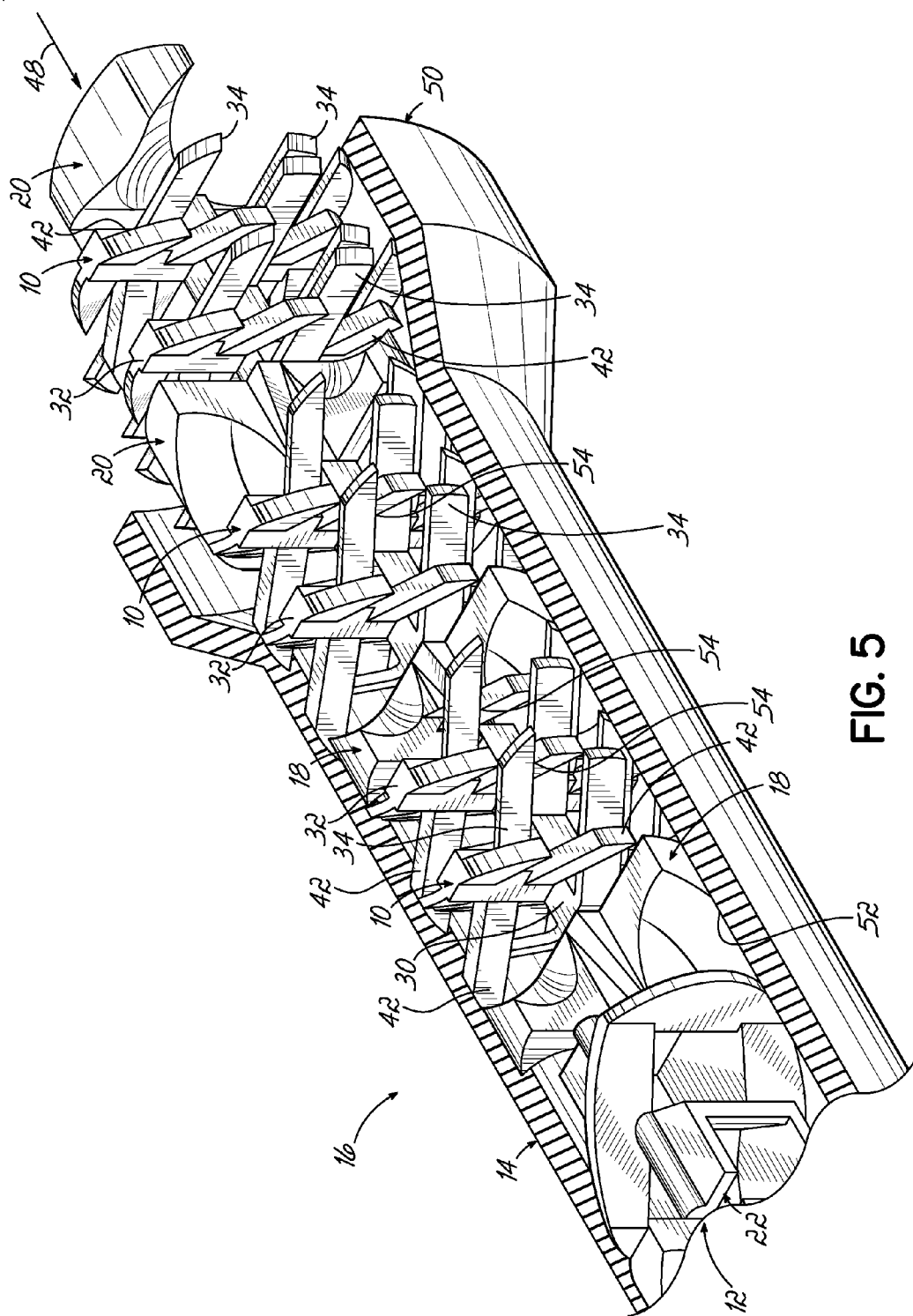


FIG. 5

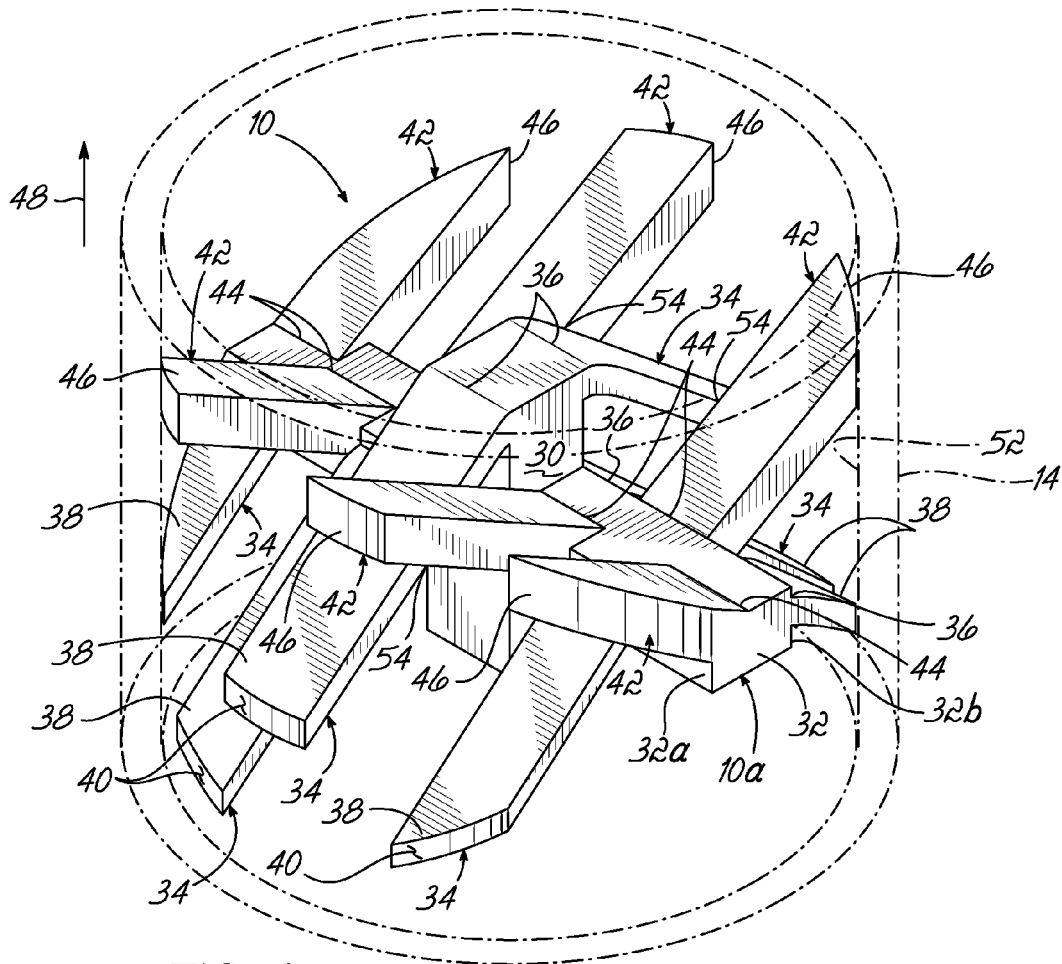


FIG. 6

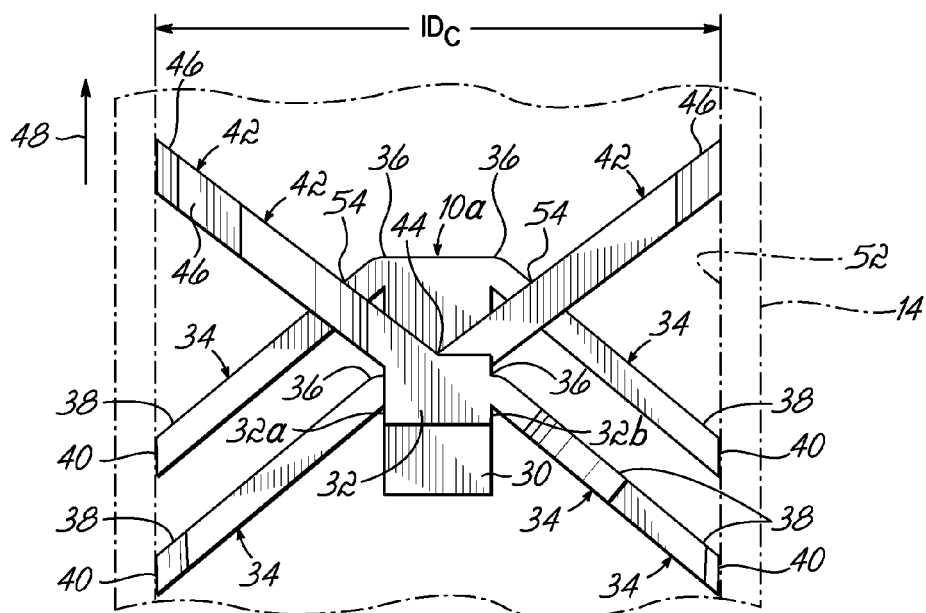


FIG. 7

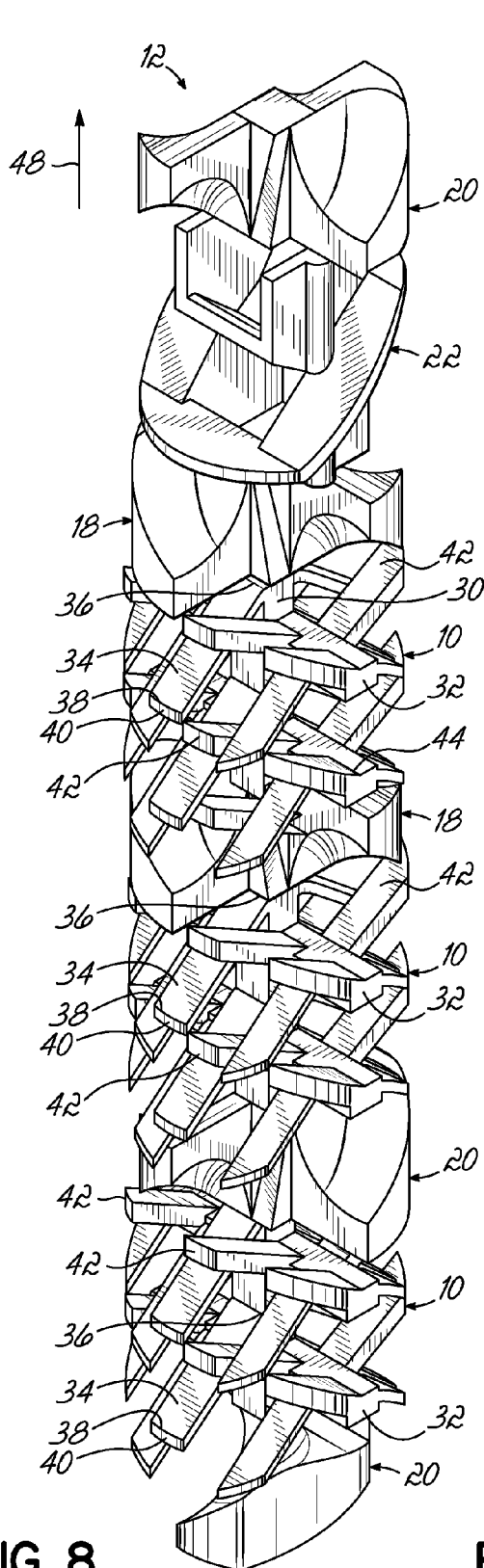


FIG. 8

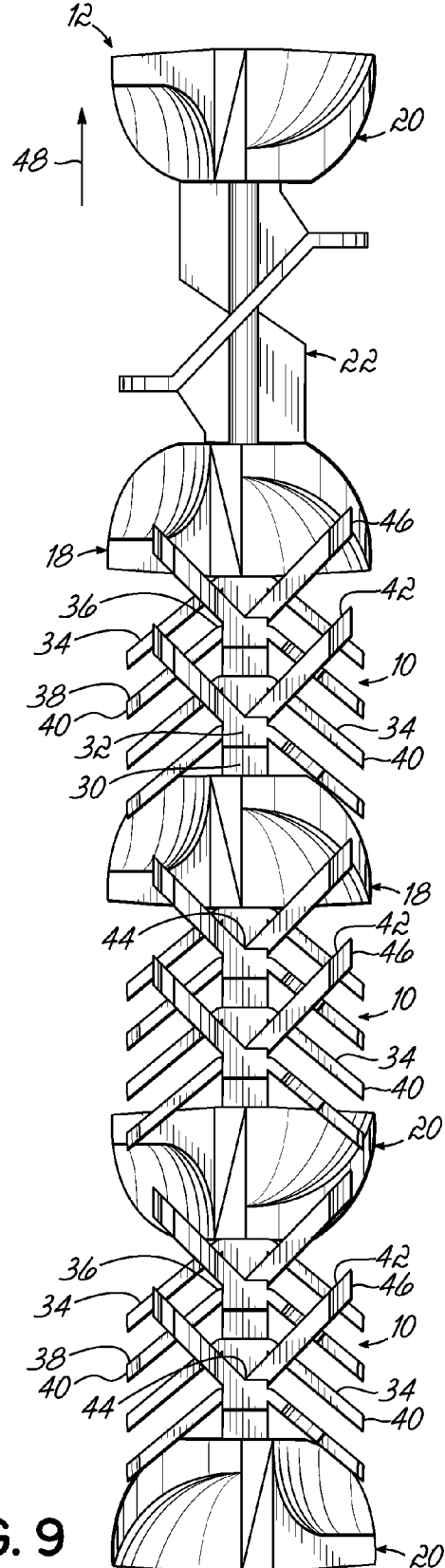


FIG. 9



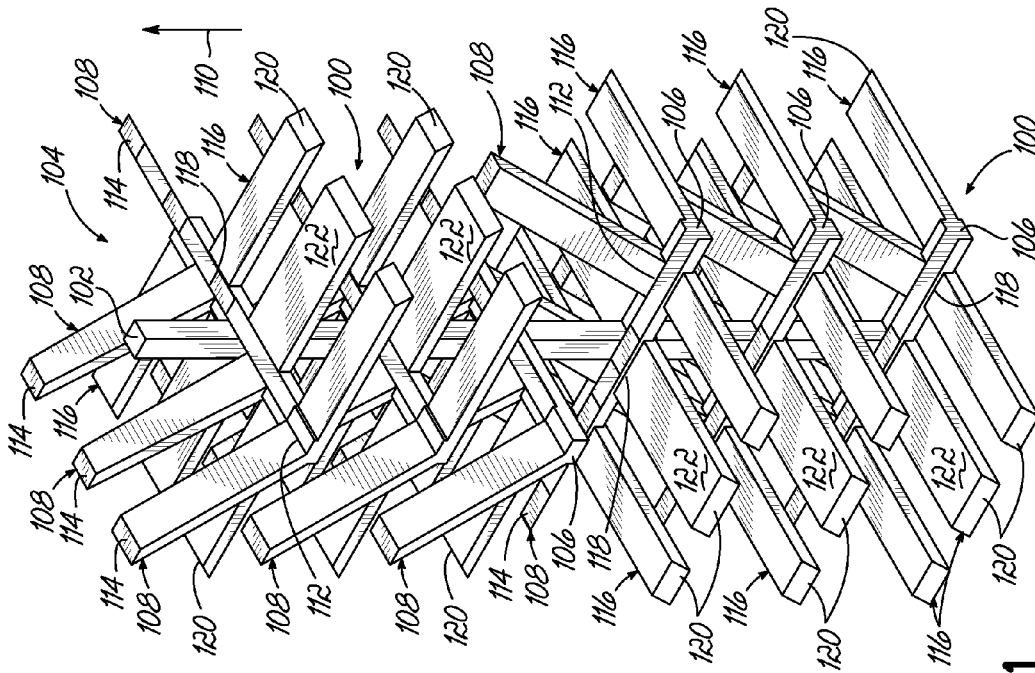


FIG. 11

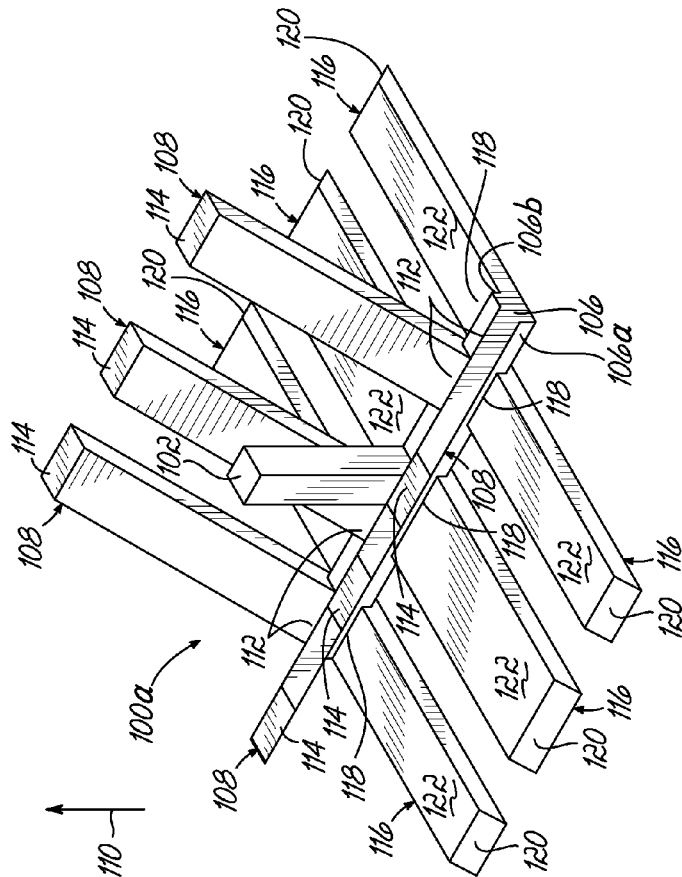
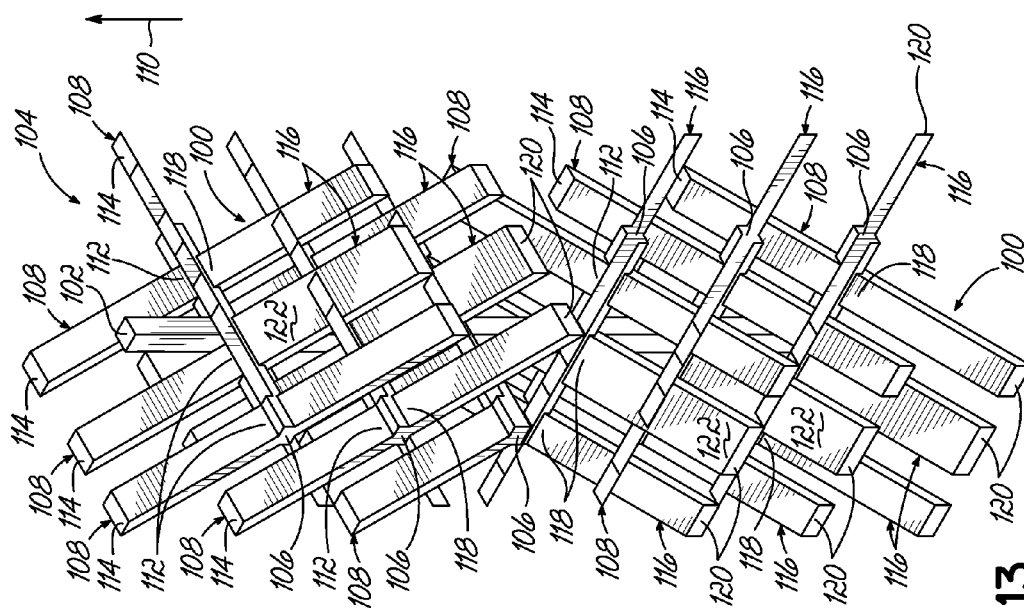
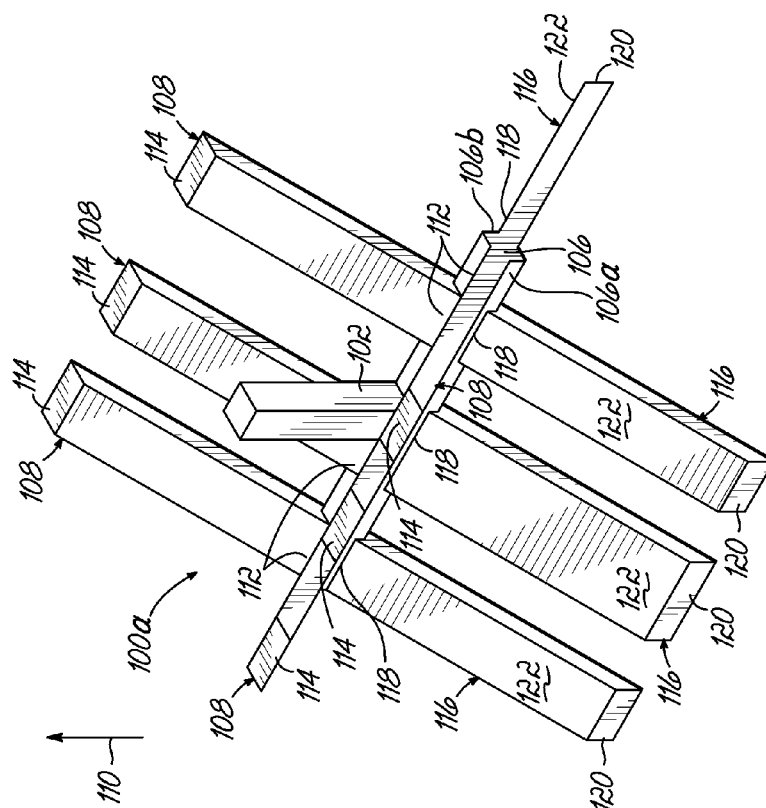


FIG. 10



**FIG. 13**



**FIG. 12**

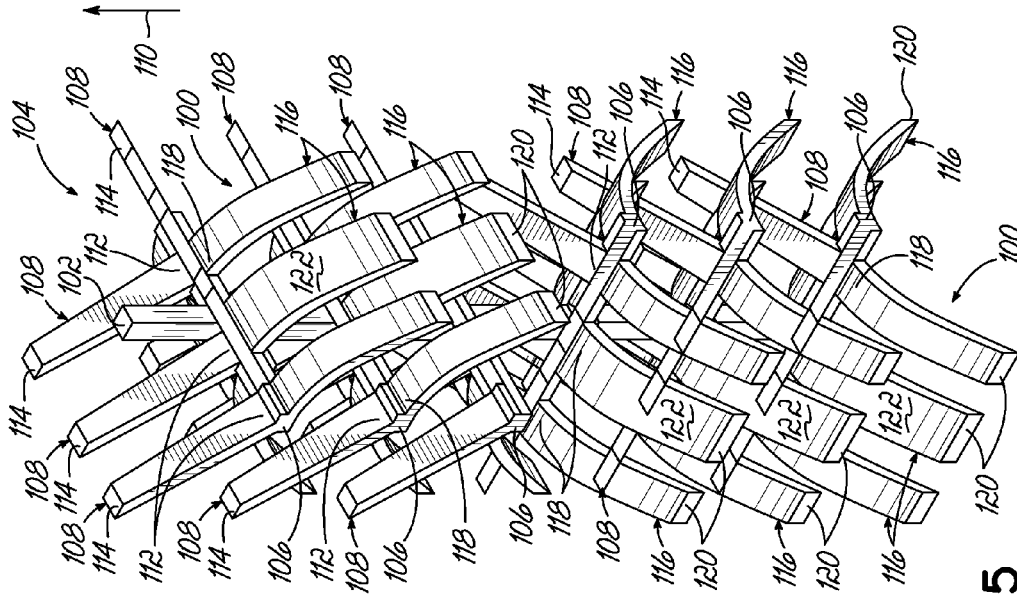


FIG. 15

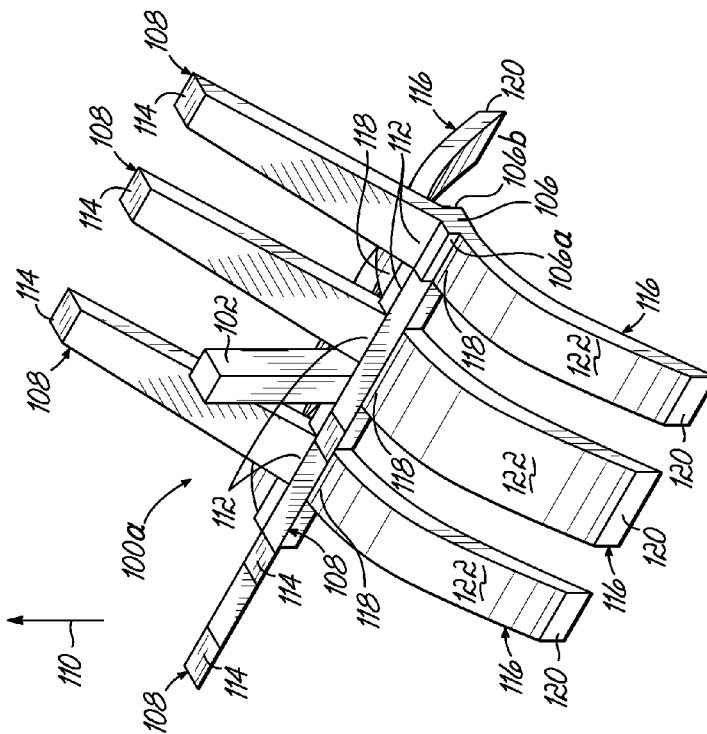


FIG. 14

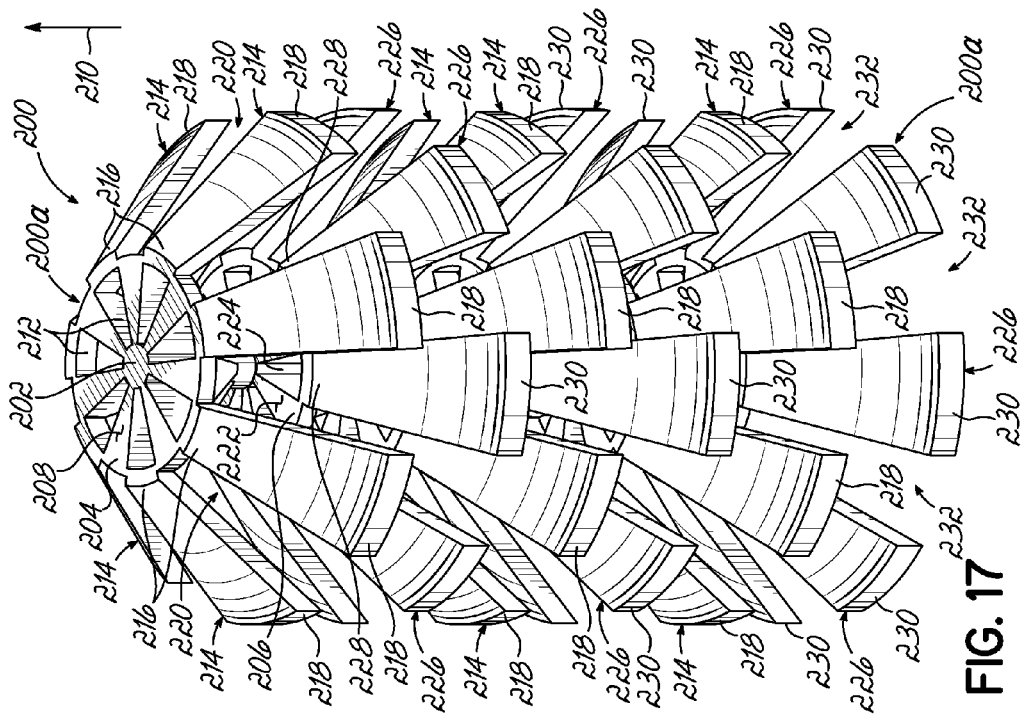


FIG. 17

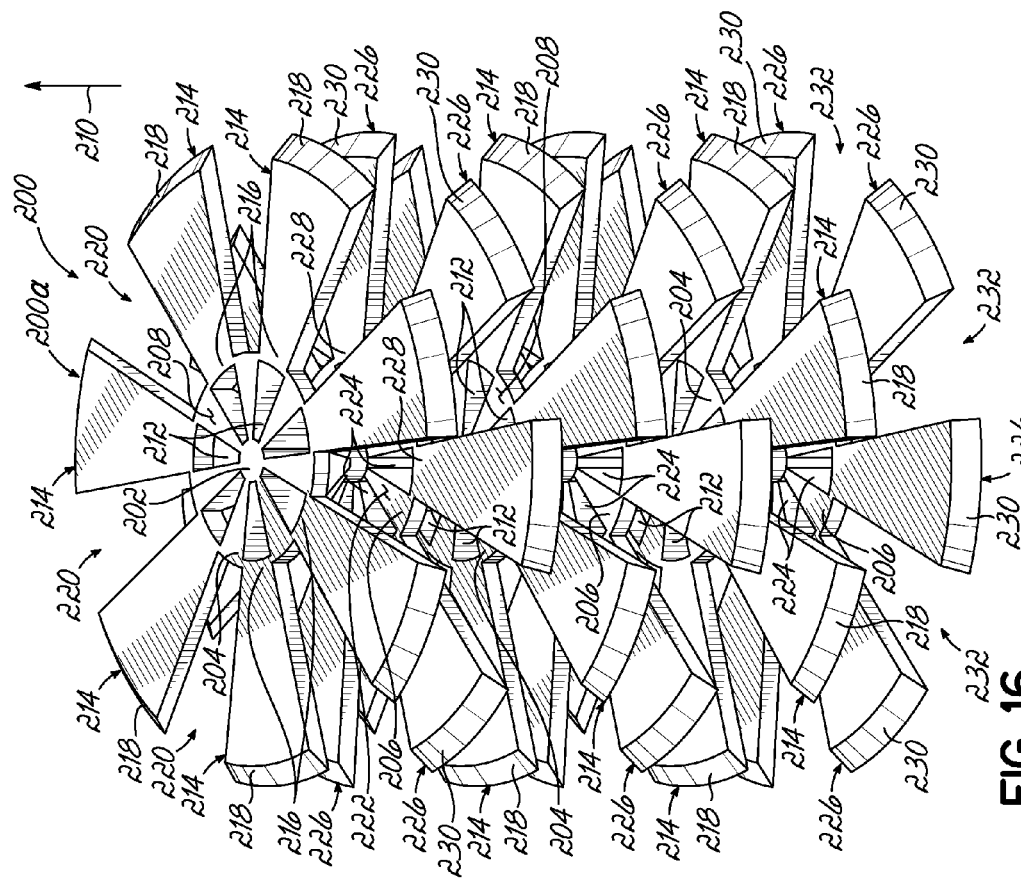


FIG. 16

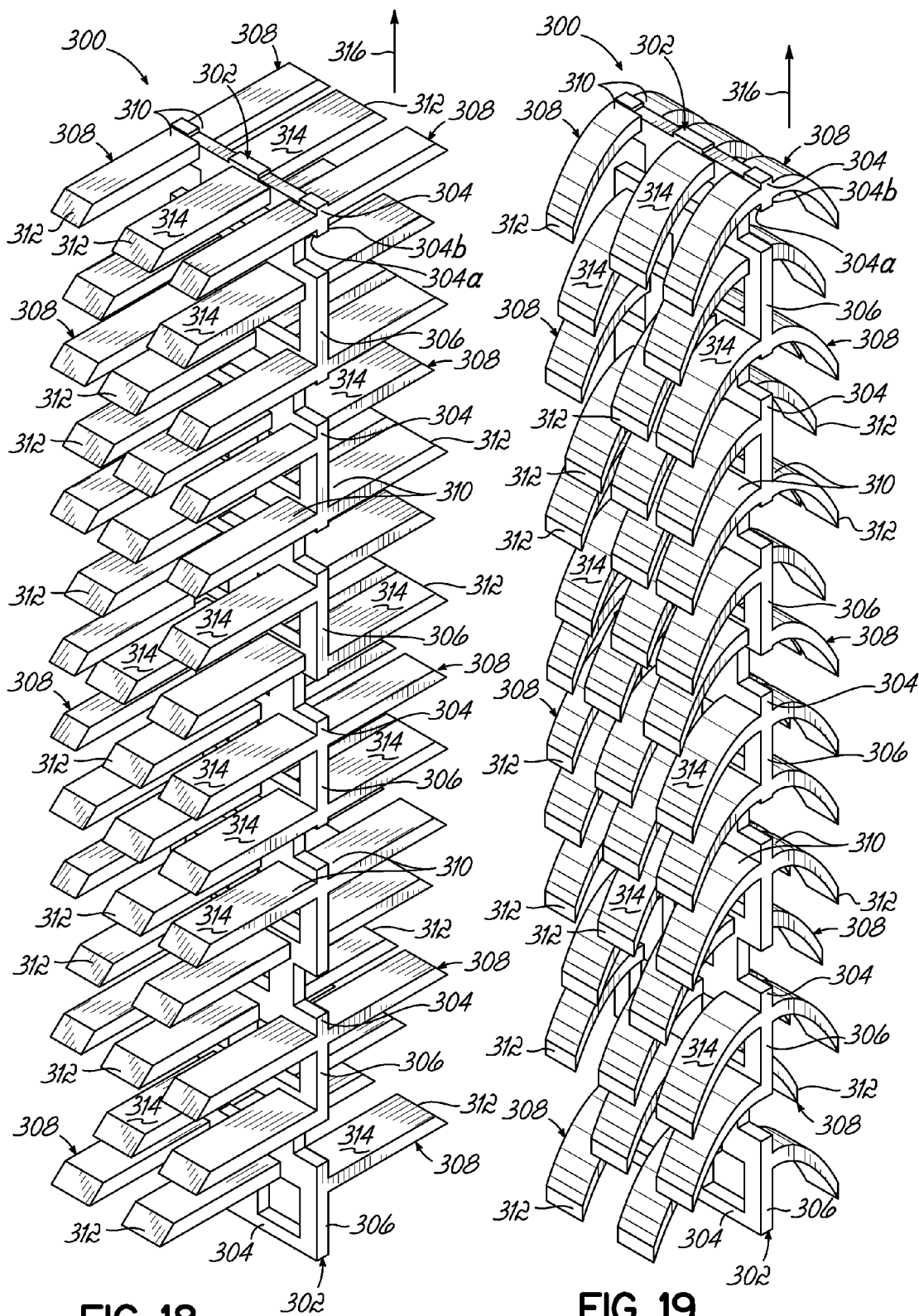


FIG. 18

FIG. 19

1

# RECONFIGURABLE MIXING BAFFLE FOR STATIC MIXER AND METHOD FOR MAKING A STATIC MIXER

## CROSS-REFERENCE TO RELATED APPLICATION

This application claims the priority of Application Ser. No. 61/553,575, filed Oct. 31, 2011, the disclosure of which is hereby incorporated by reference herein.

## FIELD OF THE INVENTION

The present invention generally relates to a fluid dispenser and more particularly, to components of a static mixer

## BACKGROUND

A number of motionless mixer types exist, such as Multi-flux, helical and others. These mixer types, for the most part, implement the same general principle to mix fluids together in a fluid dispenser. In these mixers, fluids are mixed together by dividing and recombining the fluids in an overlapping manner. This action is achieved by forcing the fluid over a series of mixing baffles of alternating geometry. Such division and recombination causes the layers of the fluids being mixed to thin and eventually diffuse past one another. This mixing process has proven to be very effective, especially with high viscosity fluids. One exemplary type of static mixer includes a series of alternating mixing baffles, of varying geometries, such as right-handed and left-handed mixing baffles disposed in a conduit to perform the continuous division and recombination.

These types of mixers are generally effective in mixing together most of the mass fluid flow, but a high number of mixing baffles must be provided to thoroughly mix the fluids, thereby increasing the overall length of the mixer. This additional length is undesirable because the fluid dispenser with a long static mixer may not be compact enough for certain dispensing operations. In order to shorten the static mixer, newer mixing baffles have been developed that include a higher number of intersecting blades or plates that form a lattice for simultaneously dividing the mass fluid flow into many more than two portions. These mixing baffles mix the mass fluid flow more rapidly and therefore enable the static mixer to be shortened considerably.

However, mixing baffles with a high number of intersecting blades are more difficult to manufacture. For example, U.S. Pat. No. 4,220,416 to Brauner et al. describes a mixing baffle molded as two V-shaped comb-like portions molded separately and intermeshed with each other before insertion into the conduit of the static mixer. The high number of intersections between blades in these mixing baffles defines a significant number of undercuts that are not moldable without specialty molding equipment or are impossible to mold. Even if these mixing baffles are molded, each mixing baffle must be molded separately rather than being molded as part of a unitary baffle stack, which is common in the static mixer field. As a result, the manufacture and assembly of each separate mixing baffle and the conduit to form a static mixer is complex, costly, and time-consuming.

Additionally, each manufactured mixing baffle must conform to a tight tolerance to properly fit within the conduit while providing a frictional fit with the conduit. Without molding each mixing baffle as a unitary baffle stack, tolerance inconsistencies between mixing baffles can make assembly of the various mixing baffles into the conduit difficult, if not

2

impossible. Thus, it would be desirable to address some of the problems associated with manufacturing static mixers including these mixing baffles with a high number of undercuts.

## SUMMARY OF THE INVENTION

According to the invention, a mixing baffle for mixing a fluid flow in a static mixer includes a mixing element support structure extending along a longitudinal direction. The mixing baffle also includes a first set of moveable mixing elements coupled to the mixing element support structure. The first set of moveable mixing elements is formed in a first configuration. When the mixing baffle is inserted into a tubular conduit, the first set of moveable mixing elements moves to a second configuration.

In one aspect, the first set of moveable mixing elements is angled from the longitudinal direction at a first angle in the first configuration, and the first set of moveable mixing elements is angled from the longitudinal direction at a second angle smaller than the first angle in the second configuration. For example, the first set of moveable mixing elements may be perpendicular to the longitudinal direction in the first configuration and angled at an acute angle from the longitudinal direction in the second configuration. In addition, each of the first set of moveable mixing elements is sized to elastically deform or otherwise move from the first configuration to the second configuration when positioned in a tubular conduit. Each of the first set of moveable mixing elements may be generally planar in the first configuration and generally non-planar in the second configuration. Each of the first set of moveable mixing elements includes an inner end connected to the mixing element support structure and a chamfered outer end configured to frictionally engage the tubular conduit.

In another aspect, the mixing baffle further includes a second set of stationary mixing elements coupled to the mixing element support structure. The second set of stationary mixing elements is not interlaced with the first set of moveable mixing elements in the first configuration, but meshes together with the first set of moveable mixing elements in the second configuration to form a lattice structure. In this regard, the first set of moveable mixing elements defines a plurality of undercuts in the second configuration, which would render the mixing element difficult to mold in the second configuration. The mixing baffle is manufactured from a non-metallic material such that the first set of moveable mixing elements is readily moved or deformed during placement in the second configuration.

In another embodiment, a static mixer for mixing a fluid flow includes a tubular conduit and at least one mixing baffle inserted into the tubular conduit. The mixing baffle includes a mixing element support structure extending along a longitudinal direction and a first set of moveable mixing elements coupled to the mixing element support structure. The first set of moveable mixing elements is formed in a first configuration. When the mixing baffle is inserted into a tubular conduit, the first set of moveable mixing elements moves to a second configuration.

The mixing baffle may be molded in series with at least one additional baffle as a unitary baffle stack. In one aspect, at least one of the additional baffles is a different type of baffle than the mixing baffle. In another aspect, at least one of the additional baffles is oriented at a different angle than the mixing baffle. The tubular conduit of the static mixer includes an inner diameter, and each of the first set of moveable mixing elements defines an element length. The element length is longer than half of the inner diameter of the tubular conduit,

3

which forces the first set of moveable elements to pivot or deform to the second configuration when inserted into the tubular conduit.

In another embodiment, a static mixer for mixing a fluid flow includes a tubular conduit defining an inner diameter and at least one mixing baffle inserted into the tubular conduit. The mixing baffle includes a longitudinal bar extending along a longitudinal direction and a first set of mixing elements pivotally coupled to the longitudinal bar. Each of the first set of mixing elements defines an element length that is longer than half of the inner diameter of the tubular conduit. Therefore, the first set of moveable elements must pivot or deform when inserted into the tubular conduit. The first set of mixing elements is pivotally coupled to the longitudinal bar so as to enable pivoting movement of the first set of mixing elements towards or away from the longitudinal direction.

In yet another embodiment, a method of manufacturing a static mixer includes molding at least one mixing baffle. The mixing baffle includes a mixing element support structure extending along a longitudinal direction and a first set of moveable mixing elements with a first configuration. The first set of moveable mixing elements is configured to move to a second configuration when the mixing baffle is inserted into a tubular conduit.

For example, the mixing elements may be formed entirely from a deformable plastic material that is also thin enough to deform as the baffle is inserted. Alternatively, mixing elements may be formed with living hinge structures that allow pivotal movement of the mixing elements even though portions thereof are rigid. The first set of moveable mixing elements is optimized for mixing fluids and defines a plurality of undercuts in the second configuration.

In still another embodiment, a method of manufacturing a static mixer includes molding at least one mixing baffle. The mixing baffle includes a mixing element support structure extending along a longitudinal direction and a first set of moveable mixing elements with a first configuration. The method also includes inserting the mixing baffle into a tubular conduit and moving the first set of moveable mixing elements from the first configuration to a second configuration as the mixing baffle is inserted into the tubular conduit.

Another method of assembling a static mixer includes inserting at least one mixing baffle having a plurality of mixing elements into a conduit. While inserting the mixing baffle, at least some of the mixing elements may be moved into a mixing configuration. To this end, the mixing baffle may be molded in a first configuration optimized for molding processes and then used in a second configuration optimized for mixing fluids.

These and other objects and advantages of the invention will become more readily apparent during the following detailed description taken in conjunction with the drawings herein.

#### BRIEF DESCRIPTION OF THE DRAWINGS

The accompanying drawings, which are incorporated in and constitute a part of this specification, illustrate embodiments of the invention and, together with a general description of the invention given above, and the detailed description of the embodiments given below, serve to explain the principles of the invention.

FIG. 1 is a perspective view of a baffle stack including a mixing baffle according to one embodiment of the current invention;

FIG. 2 is a side view of the baffle stack of FIG. 1;

4

FIG. 3 is a perspective view of at least a portion of the mixing baffle of FIG. 1, removed from the other baffles in the baffle stack and positioned in a first configuration;

FIG. 4 is a side view of the mixing baffle of FIG. 3 in the first configuration;

FIG. 5 is a perspective view of a static mixer incorporating the baffle stack of FIG. 1, while the baffle stack is inserted into a tubular conduit;

FIG. 6 is a perspective view of the mixing baffle of FIG. 3 positioned in a second configuration after insertion into a tubular conduit;

FIG. 7 is a side view of the mixing baffle of FIG. 6 in the second configuration;

FIG. 8 is a perspective view of the baffle stack of FIG. 1 including the mixing baffle in the second configuration optimized for mixing;

FIG. 9 is a side view of the baffle stack of FIG. 8;

FIG. 10 is a perspective view of at least a portion of a mixing baffle according to another embodiment of the current invention, the mixing baffle positioned in a first configuration;

FIG. 11 is a perspective view of a plurality of the mixing baffles of FIG. 10 in a baffle stack;

FIG. 12 is a perspective view of the mixing baffle of FIG. 10 positioned in a second configuration optimized for mixing;

FIG. 13 is a perspective view of a plurality of the mixing baffles of FIG. 12 in a baffle stack;

FIG. 14 is a perspective view of the mixing baffle of FIG. 10 positioned in a third configuration optimized for mixing;

FIG. 15 is a perspective view of a plurality of the mixing baffles of FIG. 14 in a baffle stack;

FIG. 16 is a perspective view of a mixing baffle according to another embodiment of the current invention, the mixing baffle positioned in a first configuration;

FIG. 17 is a perspective view of the mixing baffle of FIG. 16 positioned in a second configuration optimized for mixing;

FIG. 18 is a perspective view of a mixing baffle according to yet another embodiment of the current invention, the mixing baffle positioned in a first configuration; and

FIG. 19 is a perspective view of the mixing baffle of FIG. 18 positioned in a second configuration optimized for mixing.

#### DETAILED DESCRIPTION OF THE ILLUSTRATIVE EMBODIMENTS

Referring to FIGS. 1-9, a reconfigurable mixing baffle 10 in accordance with one embodiment of the invention is incorporated into a baffle stack 12 that is configured to be inserted into a tubular conduit 14 to form a static mixer 16 as described in greater detail below. In the illustrated embodiment, the baffle stack 12 is molded as a unitary member including at least one conventional left-handed mixing baffle 18, at least one conventional right-handed mixing baffle 20, a conventional cross flow inversion baffle 22, and a plurality of the reconfigurable mixing baffles 10. Each of the conventional baffles 18, 20, 22 illustrated in this embodiment of the baffle stack 12 is fully described in U.S. Pat. No. 7,985,020 to Pappalardo, which is assigned to the assignee of the current invention. It will be appreciated that the number and ordering of these various baffles 10, 18, 20, 22 may be modified in other embodiments of a baffle stack without departing from the scope of the current invention. Additionally, other types of conventional moldable mixing baffles may be incorporated with the baffle stack as desired. The various baffles making up the baffle stack 12 could alternatively be separately molded and coupled together in other embodiments of the invention.

5

As shown in FIGS. 1-4 and partially in FIG. 5, the reconfigurable mixing baffles 10 included in the baffle stack 12 are molded in a first configuration that is suitable for molding in series with other baffles 18, 20, 22. In this regard, the reconfigurable mixing baffles 10 do not include a high number of undercuts and interlaced mixing elements in the first configuration. As a result, the reconfigurable mixing baffles 10 may be molded in series with other mixing baffles 10 and other conventional baffles 18, 20, 22 by non-specialized, regular molding equipment. When the reconfigurable mixing baffles 10 are inserted into a tubular conduit such as the mixer conduit 14 shown in FIG. 5, the mixing baffles 10 move to a second configuration that is optimized for efficient mixing of fluids passing through the mixer conduit 14. In the second configuration as shown in FIGS. 6-9, the reconfigurable mixing baffle 10 defines a plurality of undercuts and/or an interlaced structure of mixing elements. To this end, the reconfigurable mixing baffle 10 is highly difficult or impossible to mold in the second configuration. Thus, the reconfigurable mixing baffle 10 enables baffles with complex geometries that are not directly moldable to be molded in series with other mixing baffles.

With reference to FIGS. 1-4, a reconfigurable mixing baffle 10 according to this embodiment includes a mixing element support structure 30 in the form of a longitudinal bar 30 extending along a longitudinal direction defined by the baffle stack 12 when the mixing baffle 10 is molded into the baffle stack 12. It will be understood that other types of structure may be used for the mixing element support structure 30 in other embodiments of the invention. FIGS. 1 and 2 show a plurality of these mixing baffles 10 in a baffle stack 12, while FIGS. 3 and 4 show at least a portion 10a of the mixing baffle 10. The mixing baffle 10 also includes one or more cross bars 32 coupled to the longitudinal bar 30 and extending generally perpendicular to the longitudinal direction. Projecting outwardly from the longitudinal bar 30 and the cross bars 32 are a first set of moveable mixing elements 34 (hereinafter "first set of mixing elements" 34) which extend generally perpendicular to the longitudinal direction and generally perpendicular to the cross bars 32. Each of the first set of mixing elements 34 is integrally molded with the longitudinal bar 30 or the cross bars 32. Each of the first set of mixing elements 34 extends farther outwardly from the longitudinal bar 30 than the cross bars 32, for reasons set forth in further detail below. Each mixing element 34 includes an inner end 36 connected to the longitudinal bar 30 directly or via the corresponding cross bar 32 and an outer end 38 including a chamfered surface 40. The chamfered surface 40 is configured to align with and frictionally engage the tubular conduit 14 of a static mixer 16 as described in further detail below.

The reconfigurable mixing baffle 10 of this embodiment also includes a second set of stationary mixing elements 42 coupled to the longitudinal bar 30 or the cross bars 32. Each of the second set of mixing elements 42 includes an inner end 44 connected to the corresponding cross bar 32 or the longitudinal bar 30 and an outer end 46. The outer ends 46 of the stationary mixing elements 42 and the chamfered surfaces 40 on the outer ends 38 of the first set of mixing elements 34 are rounded so that the reconfigurable mixing baffle 10 may fit into a cylindrical tubular conduit 14. It will be understood that the respective outer ends 38, 46 may not be curved in other embodiments where the tubular conduit 14 is reshaped to be rectangular in cross section or another shape in cross section. In this embodiment, each of the second set of mixing elements 42 is angled from a plane transverse to the longitudinal direction towards an insertion direction indicated by arrow 48 in the figures. Thus, the cross bar 32 shown in FIG. 3 includes

6

stationary mixing elements 42 and mixing elements formed adjacent to each other in alternating relation along opposed sides 32a, 32b of the cross bar 32.

As a result, the mixing baffle 10 defines a first configuration as molded in which the number of abutments or intersections between the mixing elements 34 and the stationary mixing elements 42 is minimized. To this end, the mixing baffle 10 does not include a high number of undercuts that are difficult to mold and impossible to mold in series with other baffles in a baffle stack 12. Thus, the mixing baffle 10 may be formed by a molding process so that the longitudinal bar 30, the cross bars 32, the first set of mixing elements 34, and the second set of mixing elements 42 are integrally formed as a unitary mixing baffle 10. Additionally, the mixing baffle 10 may be molded integrally with different types of mixing baffles having various orientations as shown in the unitary baffle stack 12 shown in FIGS. 1 and 2. In one example, the mixing baffle 10 and unitary baffle stack 12 may be injection molded from a moldable plastic material such as polypropylene. It will be understood that the mixing baffle 10 may be molded from different materials in other embodiments consistent with the invention. It will also be understood that while the mixing elements 34, 42 shown in this embodiment are blades, other types of mixing elements such as fins, wedges, webs, plates, etc. may be used as the mixing elements 34, 42 in other embodiments within the scope of the invention.

In order to move the first set of mixing elements 34 of the reconfigurable mixing baffle 10 from the first configuration to a second configuration better suited to mixing fluids, the mixing baffle 10 is inserted into a tubular conduit 14. For example, the baffle stack 12 including the mixing baffles 10 may be inserted into the inlet end 50 of the tubular conduit 14 of a static mixer 16 as shown in FIG. 5. As described above, the cross bars 32 of the mixing baffles 10 are shorter in transverse length than the reconfigurable mixing elements 34. More particularly, the cross bars 32 are sized to just frictionally engage the interior wall 52 of the tubular conduit 14. Because the first set of mixing elements 34 extends farther away from the longitudinal bar 30, the insertion of the mixing baffle 10 into the tubular conduit 14 forces each of the first set of mixing elements 34 to elastically deform or otherwise move from the first configuration (FIGS. 1-4) to the second configuration (FIGS. 6-9). For example, the first set of mixing elements 34 may be formed entirely from a deformable plastic material that is thin enough to deform as the mixing baffle 10 is inserted. Alternatively, the first set of mixing elements 34 may be formed with living hinge structures that allow pivotal movement of the mixing elements 34 even though portions thereof are rigid.

Regardless of the mechanism used to enable movement of the first set of mixing elements 34, the mixing elements 34 pivot towards and away from the longitudinal direction during insertion into the tubular conduit 14. In this embodiment, the elastic deformation of the first set of mixing elements 34 happens automatically as a result of inserting the baffle stack 12 into the static mixer 16, and no further manufacturing or assembly steps are required to prepare the mixing baffles 10 for use in the static mixer 16. To this end, the assembly of the static mixer 16 including these reconfigurable mixing baffles 10 is no more complex or time consuming than the assembly of a conventional baffle stack into a static mixer. It will be understood that the first set of mixing elements 34 may alternatively undergo inelastic or plastic deformation, or other movements, in some embodiments within the scope of the invention.

As shown most clearly in FIGS. 6-9, the first set of mixing elements 34 bends from the perpendicular orientation of the



7

first configuration to an angled orientation with respect to the longitudinal direction in the second configuration. In this regard, each of the first set of mixing elements **34** defines an element length  $L_E$  (most clearly shown in FIG. 4) measured from a center of the longitudinal bar **30** to the outer end **38**, this element length  $L_E$  being longer than half of the inner diameter  $ID_C$  of the tubular conduit **14**. As a result, the first set of mixing elements **34** is deflected upon insertion into the tubular conduit **14** so as to be angled from a plane transverse to the longitudinal direction away from the insertion direction indicated by arrow **48**. The first set of mixing elements **34** moves from a first angle with respect to the longitudinal direction to a second angle with respect to the longitudinal direction, the second angle being smaller than the first angle. As a result of this elastic deformation or bending away from the insertion direction, the first set of mixing elements **34** meshes with the adjacent second set of mixing elements **42**, which remain angled towards the insertion direction as the mixing baffle **10** is inserted into the tubular conduit **14**. Thus, the first set of mixing elements **34** and the second set of mixing elements **42** form an interlaced or lattice structure of mixing elements in the second configuration. This lattice structure is defined by a plurality of undercuts and a plurality of intersection joints **54** formed between adjacent mixing elements **34**, **42**. Consequently, the regular molding process for molding the mixing baffle **10** as a part of the unitary baffle stack **12** could not successfully mold the mixing baffle **10** in this second configuration. The high number of undercuts and joints **54** in the second configuration would prevent the mixing baffle **10** from reliably releasing from a mold in the second configuration. In summary, the reconfigurable mixing baffle **10** moves from a moldable first configuration to a second configuration that is difficult or impossible to mold when the mixing baffle **10** is inserted into the tubular conduit **14**.

The lattice structure formed by the mixing elements **34**, **42** of the mixing baffle **10** advantageously mixes two or more fluids passing through the mixing baffle **10** more thoroughly over a shorter length than a conventional mixing baffle that divides the flow into only two portions, such as the left-handed mixing baffle **18** and the right-handed mixing baffle **20**. As fluid flows through the mixing baffle **10**, the flow is subdivided into numerous portions by the first set of mixing elements **34** and the second set of mixing elements **42**. In this regard, the fluid flows through the equivalent of two comb-like structures intermeshed with one another repeatedly, which causes a single mass flow to become a high number of sub-flows that later recombine as a mixed flow. When combined with other mixing baffles that rotate and divide the flow (such as the left-handed mixing baffle **18** and the right-handed mixing baffle **20**) into a baffle stack **12**, the mixing baffles **10** enable thorough mixing of two or more fluids in a static mixer **16** with a shorter length than would be required if only left-handed mixing baffles **18** and right-handed mixing baffles **20** were used. Thus, the mixing baffle **10** is well suited to mixing fluid flow in the second configuration.

As shown most clearly in FIGS. 6 and 7, the chamfered surfaces **40** at the outer ends **38** of the first set of mixing elements **34** pivot into frictional engagement with the interior wall **52** of the tubular conduit **14** when the first set of mixing elements **34** is moved to the second configuration. Thus, the mixing baffle **10** advantageously provides an operable frictional engagement of the mixing elements **34**, **42** and the tubular conduit **14** regardless of the tolerance used to form the first set of mixing elements **34**. Any tolerance inconsistencies in the mixing elements **34** are negated by the elastic deformation of the mixing elements **34** to exactly fit the size of the tubular conduit **14** as the mixing baffle **10** is inserted into the

8

tubular conduit **14**. To this end, the reconfigurable mixing baffle **10** eliminates the problem that inconsistent tolerances of mixing baffles may lead to interference fits with the tubular conduit **14** of the static mixer **16**, which renders the baffle stack **12** difficult to insert into the tubular conduit **14**. Additionally, the automatic frictional engagement of the mixing baffle **10** and the tubular conduit **14** enables the baffle stack **12** to be reliably inserted into the static mixer **16** using a pneumatic pusher rod and relatively low insertion forces as understood in the art. In addition, this friction fit will prevent the baffle stack **12** from falling out of the tubular conduit **14** during transit, storage, and use of the static mixer **16**.

The specific angles at which the first set of mixing elements **34** deform or move is controllable by modifying the element length  $L_E$  of each mixing element **34**. For example, if the mixing elements **34** shown in FIG. 7 were increased in length from the inner end **36** to the outer end **38**, the insertion of the mixing baffle **10** into the tubular conduit **14** would force the mixing elements **34** to deflect at a greater angle than the one shown in FIG. 7. Similarly, if the mixing elements **34** were decreased in length from the inner end **36** to the outer end **38**, the angle of bend caused by insertion into the tubular conduit **14** would be less than that shown in FIG. 7. To this end, the molding and insertion of the mixing baffle **10** into the tubular conduit **14** can result in any mixing element orientation or angle that would normally be achieved by undercuts in molding processes. Furthermore, the type of elastic deformation can be modified by redesigning the mixing elements **34**, as discussed below with reference to the alternative embodiments in FIGS. 10-19. It will be understood that the element length  $L_E$  remains longer than one half of the inner diameter  $ID_C$  of the tubular conduit **14** in these embodiments in order to automatically cause the mixing baffles **10** to take the second configuration upon insertion into the tubular conduit **14**.

Consequently, a static mixer **16** including mixing baffles **10** with a first set of mixing elements **34** that define a plurality of undercuts that are difficult to mold may be manufactured by the following process. A baffle stack **12** is molded to include at least one of the mixing baffles **10** with a longitudinal bar **30** and a first set of mixing elements **34** in a first configuration. The baffle stack **12** is then inserted into a tubular conduit **14**. As the baffle stack **12** is inserted into the tubular conduit **14**, the first set of mixing elements **34** is moved from the first configuration to a second configuration that includes the plurality of undercuts, thereby rendering the mixing baffle **10** ready for mixing fluid flow in the static mixer **16**.

It will be understood that the mixing baffles **10** may be moved to the second configuration using other methods before being inserted into the tubular conduit **14** of the static mixer **16**. For example, the baffle stack **12** could be inserted into a separate tube (not shown) having a similar size as the tubular conduit **14** to elastically deform or otherwise move the first set of mixing elements **34** to the second configuration, and then the baffle stack **12** could be pushed out of the separate tube in an opposite direction directly into the tubular conduit **14** of the static mixer **16**. Using this alternative process, the first set of mixing elements **34** may be disposed in the static mixer **16** so as to be angled towards the insertion direction rather than away from the insertion direction. Other alternative methods of elastically deforming or otherwise moving the mixing elements **34** to their second configuration are also possible within the scope of this invention.

Thus, the mixing baffle **10** addresses the problems of manufacturing a static mixer **16** with mixing elements or elements that define a plurality of undercuts which are impossible to mold in series with an entire baffle stack **12**. The mixing baffle **10** automatically frictionally engages the tubu-

lar conduit **14** of the static mixer **16**, removing any insertion difficulties produced by varying mixing element tolerances. The mixing baffle **10** is moved to the second configuration, which is difficult or impossible to mold, as a result of insertion into a tubular conduit **14**, thereby removing any additional manufacturing or assembly steps required to generate the static mixer **16**. The inclusion of the reconfigurable mixing baffles **10** increases the mixing effectiveness of the baffle stack **12** and enables an advantageous overall reduction of the length of the static mixer.

An alternative embodiment of the mixing baffle **100** is illustrated in FIGS. **10-15**. Each mixing baffle **100** includes one or more of the repeating mixing baffle portions **100a** shown in detail in FIG. **10**. Similar to the first embodiment of the mixing baffle **10**, the mixing baffle **100** is molded in a first configuration and is configured to move to a second or third configuration optimized for mixing fluids when the mixing baffle **100** is inserted into a tubular conduit (not shown). In the second and third configurations, the mixing elements defining the mixing baffle **100** define a plurality of undercuts that are difficult or impossible to mold in series with other mixing baffles.

With reference to FIG. **10**, the mixing baffle **100** in the first configuration includes a mixing element support structure **102** in the form of a longitudinal bar **102** extending in a longitudinal direction as defined by the baffle stack **104** shown in FIG. **11**. The mixing baffle **100** also includes at least one cross bar **106** extending perpendicular to the longitudinal direction. Each cross bar **106** connected to the longitudinal bar **102** of a single mixing baffle **100** is oriented in the same direction and is parallel to the other cross bars **106**. A second set of stationary mixing elements **108** extends in alternating relation from opposed sides **106a**, **106b** of the cross bar **106**. The second set of mixing elements **108** extends towards an insertion direction indicated by arrow **110** from inner ends **112** at the cross bar **106** to outer ends **114**. The second set of mixing elements **108** therefore produces a V-shaped comb-like portion of the mixing baffle **100**.

The mixing baffle **100** also includes a first set of moveable mixing elements **116** (hereinafter first set of mixing elements **116**) extending in alternating relation from the opposed sides **106a**, **106b** of the cross bar **106**. The first set of mixing elements **116** extends generally perpendicular to the longitudinal direction and generally perpendicular to the cross bar **106**, from inner ends **118** at the cross bar **106** to outer ends **120**. Each of the first set of mixing elements **116** also includes a deflection face **122** oriented towards the insertion direction indicated by arrow **110**. To this end, each of the mixing elements **116** is generally planar and does not intermesh with other mixing elements in the first configuration as molded, thereby reducing or eliminating any undercuts that are difficult to mold in series with other mixing baffles.

As shown in FIG. **11**, multiple mixing baffle portions **100a** are positioned adjacent to one another along the longitudinal direction to form the mixing baffle **100**. Also as shown in FIG. **11**, two adjacent mixing baffles **100** in the baffle stack **104** may be reoriented with respect to one another 90 degrees or some other angle such that the mixing elements **108**, **116** change orientation from one mixing baffle **100** to the next. This reorientation of adjacent mixing baffles **100** improves the efficiency or mixing thoroughness per unit length of the baffle stack **104**. It will be understood that while the various mixing elements **108**, **116** do not have rounded edges and are configured to be inserted into a rectangular tubular conduit, the mixing elements **108**, **116** could be reconfigured in other embodiments of the invention so as to fit in tubular conduits of cylindrical or other shapes.

Each of the first set of mixing elements **116** extends farther outwardly from the cross bar **106** than the corresponding second set of mixing elements **108**. Thus, when the mixing baffle **100** is inserted into a tubular conduit, the tubular conduit elastically (or plastically) deforms the first set of mixing elements **116** from the generally perpendicular first configuration to either a generally planar angled second configuration shown in FIGS. **12** and **13** or a generally non-planar arcuate third configuration shown in FIGS. **14** and **15**. In this regard, the deflection face **122** of each mixing element **116** abuts the tubular conduit and is forced inwardly towards the longitudinal bar **102** as the mixing baffle **100** is inserted into the tubular conduit. In other words, each mixing element **116** is bent away from the insertion direction to a more angled (FIGS. **12** and **13**) or arcuate (FIGS. **14** and **15**) shape. Various factors may determine whether the first set of mixing elements **116** deforms into the planar angled second configuration or the arcuate third configuration, including but not limited to: elasticity of the material forming the mixing elements **116**, the size of the tubular conduit, and other factors. Similar to the first embodiment, the bending of the first set of mixing elements **116** produces a frictional engagement between the mixing elements **116** and the tubular conduit at the deflection faces **122**. The first set of mixing elements **116** may also intermesh with the second set of mixing elements **108** in the second and third configurations. As a result, the mixing baffle **100** defines a plurality of undercuts in the second and third configurations that are difficult if not impossible to mold in that second or third configuration. The mixing baffle **100** is optimized for mixing in both the second and third configurations. Thus, the mixing baffles **100** enable the generation of a baffle stack **104** by molding that would not have been moldable if the first set of mixing elements **116** were molded in the second configuration.

Another embodiment of a mixing baffle **200** in accordance with the invention is shown in FIGS. **16** and **17**. Similar to the first embodiment of the mixing baffle **10**, the mixing baffle **200** is molded in a first configuration (FIG. **16**) and is configured to move to a second configuration (FIG. **17**) optimized for mixing fluids when the mixing baffle **200** is inserted into a tubular conduit (not shown). In the second configuration, the mixing elements defining the mixing baffle **200** define a plurality of undercuts that are difficult or impossible to mold in series with other mixing baffles.

Referring to FIG. **16**, the mixing baffle **200** is composed of a plurality of repeating mixing baffle portions **200a**. Each mixing baffle portion **200a** includes a mixing element support structure **202** in the form of a longitudinal bar **202** extending in a longitudinal direction, a first conical portion **204** surrounding the longitudinal bar **202**, and a second conical portion **206** adjacent to the first conical portion **204** and surrounding the longitudinal bar **202**. The first conical portion **204** includes an end surface **208** facing towards a direction of insertion indicated by arrow **210**. The first conical portion **204** tapers in cross-sectional dimension from the end surface **208** towards the second conical portion **206**. The first conical portion **204** also includes a plurality of through apertures **212** configured to permit flow through the center portion of the mixing baffle **200**. The mixing baffle **200** includes a first set of moveable mixing elements **214** extending radially outwardly in a direction perpendicular to the longitudinal direction from inner edges **216** to outer edges **218**. Each of the first set of mixing elements **214** is spaced from one another so as to define first gaps **220** for fluid flow between the mixing elements **214**.

In a similar manner, the second conical portion **206** includes an end surface **222** facing towards a direction of

11

insertion indicated by arrow **210**. The second conical portion **206** tapers in cross-sectional dimension from the end surface **222** away from the first conical portion **204**. The second conical portion **206** also includes a plurality of through apertures **224** configured to permit flow through the center portion of the mixing baffle **200**. The mixing baffle **200** includes a second set of moveable mixing elements **226** extending radially outwardly in a direction perpendicular to the longitudinal direction from inner edges **228** to outer edges **230**. Each of the second set of mixing elements **226** is spaced from one another so as to define second gaps **232** for fluid flow between the mixing elements **226**. The first set of mixing elements **214** is generally aligned with the second gaps **232**, and the second set of mixing elements **226** is generally aligned with the first gaps **220**. It will be understood that the first and second pluralities of mixing elements **214**, **226** could also be aligned at different rotational positions in other embodiments of the mixing baffle **200** within the scope of this invention.

The first and second pluralities of mixing elements **214**, **226** are sized such that when the mixing baffle **200** is inserted into a tubular conduit, the tubular conduit elastically deforms the mixing elements **214**, **226** from the perpendicular orientation of the first configuration to an angled orientation in a second configuration shown in FIG. **17**. In this regard, each mixing element **214**, **226** is forced inwardly towards the longitudinal bar **202** and away from the insertion direction as the mixing baffle **200** is inserted into the tubular conduit. Thus, the mixing elements **214**, **226** move from a first angle with respect to the longitudinal direction to a second angle with respect to the longitudinal direction, the second angle being smaller than the first angle. Similar to the first embodiment, the bending of the first and second pluralities of mixing elements **214**, **226** produces a frictional engagement between the outer edges **218**, **230** of the mixing elements **214**, **226** and the tubular conduit. Although the mixing elements **214**, **226** do not intermesh as in previously-described embodiments, the mixing baffle **200** still defines a plurality of undercuts in the second configuration that present obstacles that can prevent molding. Thus, the mixing baffle **200** enables the generation of a baffle stack by molding that would not have been moldable if the first and second pluralities of mixing elements **214**, **226** were molded in the second configuration.

Another embodiment of a mixing baffle **300** in accordance with the invention is shown in FIGS. **18** and **19**. Similar to the first embodiment of the mixing baffle **10**, the mixing baffle **300** is molded in a first configuration (FIG. **18**) and is configured to move to a second configuration (FIG. **19**) optimized for mixing fluids when the mixing baffle **300** is inserted into a tubular conduit (not shown). In the second configuration, the mixing elements defining the mixing baffle **300** define a plurality of undercuts that are difficult or impossible to mold in series with other mixing baffles.

Referring to FIG. **18**, the mixing baffle **300** includes a mixing element support structure **302** in the form of a central frame **302** that extends along a longitudinal direction. The central frame **302** includes a plurality of cross bars **304** extending perpendicular to the longitudinal direction and a plurality of connecting bars **306** extending between adjacent pairs of cross bars **304**. The mixing baffle **300** also includes a first set of moveable mixing elements **308** (hereinafter first set of mixing elements **308**) extending from opposing sides **304a**, **304b** of each cross bar **304**. The lateral positioning and the number of mixing elements **308** extending from each cross bar **304** may be varied without departing from the scope of the invention. Each of the mixing elements **308** extends perpendicular to the longitudinal direction in a first configuration from an inner edge **310** at the corresponding cross bar

12

**304** to an outer edge **312** configured to abut a tubular conduit (not shown). Each of the mixing elements **308** also includes a deflection face **314** extending between the inner edge **310** and the outer edge **312**, the deflection face **314** directed towards a direction of insertion indicated by arrow **316**.

Each of the first set of mixing elements **308** is sized such that when the mixing baffle **300** is inserted into a tubular conduit, the tubular conduit elastically deforms the mixing elements **308** from the perpendicular and generally linear orientation of the first configuration to a generally non-planar arcuate orientation in a second configuration shown in FIG. **19**. In this regard, the deflection face **314** of each mixing element **308** is forced inwardly towards the central frame **302** and away from the insertion direction as the mixing baffle **300** is inserted into the tubular conduit. Similar to the first embodiment, the bending of the mixing elements **308** produces a frictional engagement between the outer edges **312** of the mixing elements **308** and the tubular conduit. Although the mixing elements **308** do not intermesh as in previously-described embodiments, the mixing baffle **300** still defines a plurality of undercuts in the second configuration that present obstacles that can prevent molding. Thus, the mixing baffle **300** enables the generation of a baffle stack by molding that would not have been moldable if the first set of mixing elements **308** were molded in the second configuration.

While the present invention has been illustrated by a description of several embodiments, and while such embodiments have been described in considerable detail, there is no intention to restrict, or in any way limit, the scope of the appended claims to such detail. Additional advantages and modifications will readily appear to those skilled in the art. For example, the various embodiments of the mixing baffle **10**, **100**, **200**, **300** can be adapted for use in any type of tubular mixer conduit, including rectangular-shaped and circular-shaped mixer conduits. Therefore, the invention in its broadest aspects is not limited to the specific details shown and described. The various features disclosed herein may be used in any combination necessary or desired for a particular application. Consequently, departures may be made from the details described herein without departing from the spirit and scope of the claims which follow.

What is claimed is:

1. A mixing baffle for mixing a fluid flow in a static mixer, comprising:

- a mixing element support structure extending along a longitudinal direction;
- a set of moveable mixing elements coupled to the mixing element support structure, the set of moveable mixing elements being formed in a first configuration; and
- a set of stationary mixing elements coupled to the mixing element support structure, the set of stationary mixing elements not interlaced with the set of moveable mixing elements when in the first configuration,

wherein the set of moveable mixing elements moves from the first configuration to a second configuration when the mixing baffle is inserted into a tubular conduit, and wherein the set of moveable mixing elements and the set of stationary mixing elements alternately mesh together to form an interlaced lattice structure when the set of moveable mixing elements moves to the second configuration.

2. The mixing baffle of claim 1, wherein the set of moveable mixing elements is angled from the longitudinal direction at a first angle in the first configuration, and the set of moveable mixing elements is angled from the longitudinal direction at a second angle smaller than the first angle in the second configuration.

## 13

3. The mixing baffle of claim 2, wherein the set of moveable mixing elements is perpendicular to the longitudinal direction in the first configuration, and the set of moveable mixing elements is angled at an acute angle from the longitudinal direction in the second configuration.

4. The mixing baffle of claim 1, wherein each of the set of moveable mixing elements elastically deforms from the first configuration to the second configuration when positioned in a tubular conduit.

5. The mixing baffle of claim 1, wherein each of the set of moveable mixing elements includes an inner end connected to the mixing element support structure and a chamfered outer end configured to frictionally engage the tubular conduit when the set of moveable mixing elements is in the second configuration after insertion into the tubular conduit.

6. The mixing baffle of claim 1, wherein each of the set of moveable mixing elements is generally planar in the first configuration and is generally non-planar in the second configuration.

7. The mixing baffle of claim 1, wherein the set of moveable mixing elements defines a plurality of undercuts in the second configuration.

8. The mixing baffle of claim 1, wherein the set of moveable mixing elements includes multiple mixing element surfaces separated by apertures configured to enable flow to move around and between the mixing element surfaces when mixing the fluid flow, the multiple mixing element surfaces being arranged at different orientations at different points along a longitudinal length of the mixing baffle, to thereby force the fluid flow to divide and move at all portions of the tubular conduit.

9. A static mixer for mixing a fluid flow, comprising:  
a tubular conduit; and

at least one mixing baffle inserted into the tubular conduit, the mixing baffle further comprising:

a mixing element support structure extending along a longitudinal direction;

a set of moveable mixing elements coupled to the mixing element support structure, the set of moveable mixing elements being formed in a first configuration; and

a set of stationary mixing elements coupled to the mixing element support structure, the set of stationary mixing elements not interlaced with the set of moveable mixing elements when in the first configuration,

wherein the set of moveable mixing elements moves from the first configuration to a second configuration when the mixing baffle is inserted into a tubular conduit, and wherein the set of moveable mixing elements and the set of stationary mixing elements alternately mesh together to form an interlaced lattice structure when the set of moveable mixing elements moves to the second configuration.

10. The static mixer of claim 9, wherein the at least one mixing baffle is non-metallic.

11. The static mixer of claim 9, wherein the at least one mixing baffle is molded in series with at least one additional baffle to form a unitary baffle stack.

12. The static mixer of claim 11, wherein at least one of the additional baffles is a different type of baffle than the at least one mixing baffle.

13. The static mixer of claim 11, wherein at least one of the additional baffles is oriented at an angle from the at least one mixing baffle.

14. The static mixer of claim 9, wherein the set of moveable mixing elements is angled from the longitudinal direction at a first angle in the first configuration, and the set of moveable

## 14

mixing elements is angled from the longitudinal direction at a second angle smaller than the first angle in the second configuration.

15. The static mixer of claim 14, wherein the set of moveable mixing elements is perpendicular to the longitudinal direction in the first configuration, and the set of moveable mixing elements is angled at an acute angle from the longitudinal direction in the second configuration.

16. The static mixer of claim 9, wherein each of the set of moveable mixing elements is sized to elastically deform from the first configuration to the second configuration when positioned in a tubular conduit.

17. The static mixer of claim 9, wherein each of the set of moveable mixing elements includes an inner end connected to the mixing element support structure and a chamfered outer end configured to frictionally engage the tubular conduit when the set of moveable mixing elements is in the second configuration after insertion into the tubular conduit.

18. The static mixer of claim 9, wherein each of the set of moveable mixing elements is generally planar in the first configuration and is generally non-planar in the second configuration.

19. The static mixer of claim 9, wherein the set of moveable mixing elements defines a plurality of undercuts in the second configuration.

20. The static mixer of claim 9, wherein the tubular conduit includes an inner diameter, each of the set of moveable mixing elements defines an element length, and the element length is longer than half of the inner diameter of the tubular conduit.

21. The static mixer of claim 20, wherein

the mixing baffle includes a longitudinal bar extending along a longitudinal direction, and the set of moveable mixing elements is pivotally coupled to the longitudinal bar.

22. The static mixer of claim 21, wherein the set of moveable mixing elements is pivotally coupled to the longitudinal bar so as to enable pivoting movement of the set of moveable mixing elements towards or away from the longitudinal direction.

23. The static mixer of claim 9, wherein the set of moveable mixing elements includes multiple mixing element surfaces separated by apertures configured to enable flow to move around and between the mixing element surfaces when mixing the fluid flow, the multiple mixing element surfaces being arranged at different orientations at different points along a longitudinal length of the at least one mixing baffle, to thereby force the fluid flow to divide and move at all portions of the tubular conduit.

24. A method of manufacturing a static mixer, comprising: molding at least one mixing baffle so that the at least one mixing baffle includes:

a mixing element support structure extending along a longitudinal direction;

a set of moveable mixing elements coupled to the mixing element support structure, the set of moveable mixing elements being formed in a first configuration; and

a set of stationary mixing elements coupled to the mixing element support structure, the set of stationary mixing elements not interlaced with the set of moveable mixing elements when in the first configuration;

inserting the at least one mixing baffle into a tubular conduit; and

moving the set of moveable mixing elements from the first configuration to a second configuration as the at least one mixing baffle is inserted into the tubular conduit, wherein the set of moveable mixing elements and the set

of stationary mixing elements alternately mesh together to form an interlaced lattice structure when the set of moveable mixing elements moves to the second configuration.

25. The method of claim 24, wherein the set of moveable mixing elements elastically deforms to move from the first configuration to the second configuration. 5

26. The method of claim 24, wherein the set of moveable mixing elements is angled from the longitudinal direction at a first angle in the first configuration, and the set of moveable mixing elements is angled from the longitudinal direction at a second angle smaller than the first angle in the second configuration. 10

27. The method of claim 24, wherein the set of moveable mixing elements moves from generally planar in the first configuration to generally non-planar in the second configuration. 15

28. The method of claim 24, wherein the at least one mixing baffle further includes a set of stationary mixing elements not interlaced with the set of moveable mixing elements when in the first configuration, and the set of stationary mixing elements is meshed together with the set of moveable mixing elements in the second configuration. 20

\* \* \* \* \*